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D4 Digital Channel Bank Family:

The *SLC*™-96 System

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The SLC-96 system is a digital subscriber carrier system that can carry up to 96 subscriber channels, when fully equipped, between a Central Office Terminal (COT) and a Remote Terminal (RT), using T1 digital lines. Typical economic applications are for expanding the service capability of existing cable plant or for new wire center deferral. Recent application studies show that SLC-96 systems will be economically attractive in many permanent subscriber applications. In addition to Message Telephone Service (MTS), the system can provide coin services, voice-frequency special services, and digital data services. The SLC-96 system is based on the transmission and physical format of the D4 system used for interoffice trunks. The system employs µ255 pulse code modulation (PCM) for voice transmission and, as a result, will allow the direct interface of the RT with a digital central office. Its maintenance features include channel and drop testing from a local test desk; single-ended, active, T1 fault-locating; automatic T1 line protection; extensive local and remote alarm displays; and outputs that can be transmitted to a remote operations center such as the Switching Control Center (SCC). The channel and drop testing scheme requires a Pair Gain Test Controller (PGTC) to be installed in each wire center containing one or more SLC-96 systems. Various other features that will enhance the application of the SLC-96 system in the loop plant include extended range channel units, remote T1 line power feed, and a variety of RT enclosures.*

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* *SLC* is a trademark of Western Electric.

I. INTRODUCTION

The subscriber loop is generally represented by pairs of metallic conductors that connect the customer's premises to the telepbone network through a central office serving a locality. As low-cost electronic technologies continue to emerge, the subscriber loop, which was previously entirely metallic, is now being viewed as a potentially large market for the application of these technologies.[1] The electronic systems tbat bave evolved to reduce the cost of growth in the loop plant are called pair gain systems. Most recently, the digital carrier-type pair gain systems appear to be well suited to growth of the network because of their high pair gain ratios realized by multiplexing with optional concentration and for their excellent signal quality resulting from digital transmission.

The digital subscriber carrier system is being used in increasing numbers today in the Bell System to bring toll-quality channels to customers in both suburban and rural areas. The *SLC*-96 system is a new, versatile pair gain system that provides an economic means of linking subscriber lines to the central office.[2,3] Like its predecessors, the *SLC*-96 system brings electronic technology to the loop plant, and in addition, the system may be used with the D4 channel bank to provide a new synergy between trunk and loop applications of digital carrier. Representing a significant step toward the Bell System's digital network of the future, the *SLC*-96 system can handle the broad spectrum of telecommunications services needed to meet today's widely varying requirements for both voice message and special communication services.

The new *SLC*-96 system has the versatility to serve rapidly growing suburban, as well as rural, areas with such benefits as conventional facility relief, wire center deferrals and replacements, improvements in transmission quality, and new communication arrangements for business complexes.[4,5] The *SLC*-96 system is a digital system that uses $\mu 255$ pulse code modulation, as does the D4 channel bank, and enables the RT to interface directly with a digital central office. Many of the D4 channel units may be used interchangeably in the *SLC*-96 or D4 systems. In addition, new dual-channel subscriber units have been designed exclusively for the *SLC*-96 system to permit as many as 96 single- or multi-party customer lines to be served from a *SLC*-96 channel bank. The full range of customer services offered by the *SLC*-96 system includes single-party, multi-party, and coin services. It can also provide many trunk and special services, including dataport, by using the standard D4 channel units. This paper gives a concise description of the *SLC*-96 system, highlighting its roots in the D4 system. Many of the unique features incorporated in the design of the

SLC-96 system will be described in detail in a future issue of the Bell System Technical Journal.

II. BASIC SYSTEM OPERATION

2.1 System components

The *SLC*-96 system consolidates message channels using time-division multiplexing and optional digital concentration for transmission over digital PCM links, which are standard T-carrier today and will include the more advanced lightwave systems tomorrow. The basic *SLC*-96 terminals are designed to operate between the central office and a remote location serving as many as 96 subscriber lines per system. They operate over four T1 lines and can automatically transfer to a fifth protection line to increase system availability. Three T1 lines are required when the system is concentrated or operating in a pure special services mode. The basic system components of the *SLC*-96 system are:

(*i*) COT equipment and associated apparatus located in the serving central office

(*ii*) RT equipment and apparatus located in the area to be served

(*iii*) Digital lines between the two terminals (in this article, however, digital lines are assumed to be standard T1 lines).

The primary element of the COT and RT equipment is the *SLC*-96 channel bank. The *SLC*-96 channel bank may be configured in three different operating modes: (*i*) a carrier-only mode, (*ii*) a carrier-concentrator mode, and (*iii*) a special services mode. Typical configurations illustrating these modes of operation are shown in Figs. 1, 2, and 3.

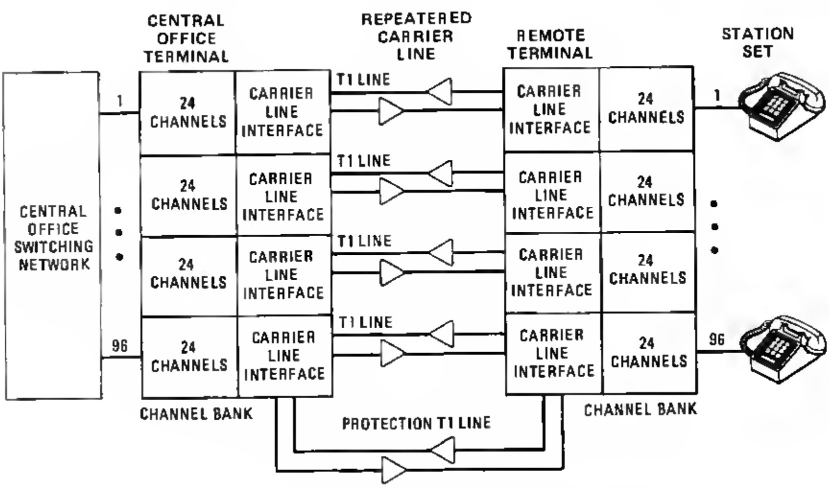

Fig. 1—The *SLC*-96 system—carrier-only configuration, Mode 1.

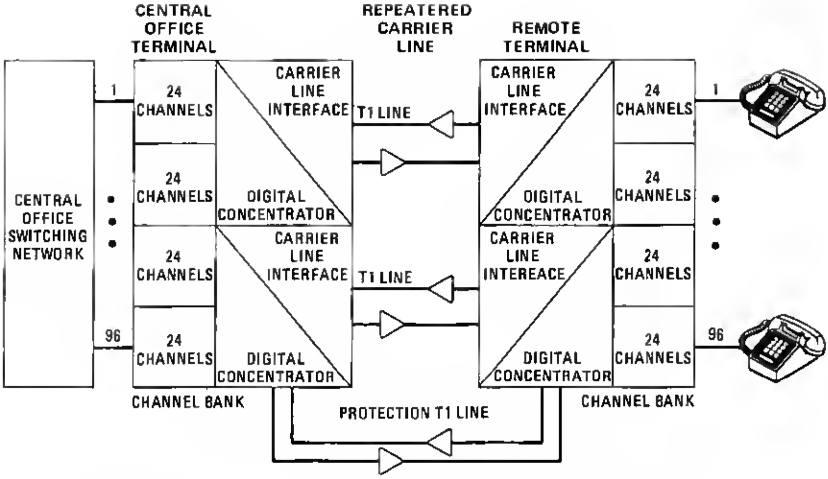

Fig. 2—The *SLC*-96 system—carrier concentrator configuration, Mode 2.

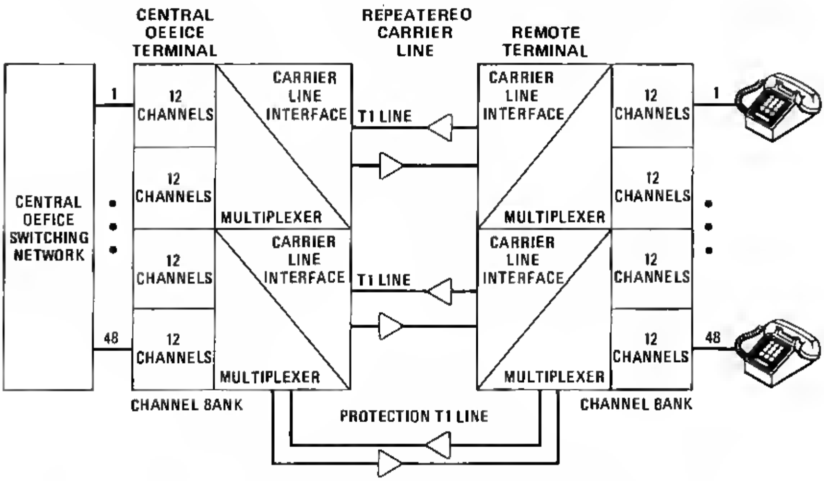

Fig. 3—The *SLC*-96 system—special services configuration, Mode 3.

Physically, the *SLC*-96 channel bank consists of four shelves, as shown in Fig. 4. Each shelf contains 12 slots for channel-unit plug-ins and four additional slots for common equipment. Each MTS cbannel unit contains two channels for each plug-in, while coin, special service, and dataport channel units contain one channel each. Therefore, each non-MTS channel unit displaces two MTS subscriber channels. Since non-MTS channel units are typically D4 channel units, the *SLC*-96 backplane arrangement is very similar to the D4 backplane. The physical size of the *SLC*-96 channel bank is identical to that of the 48-cbannel D4 channel bank.

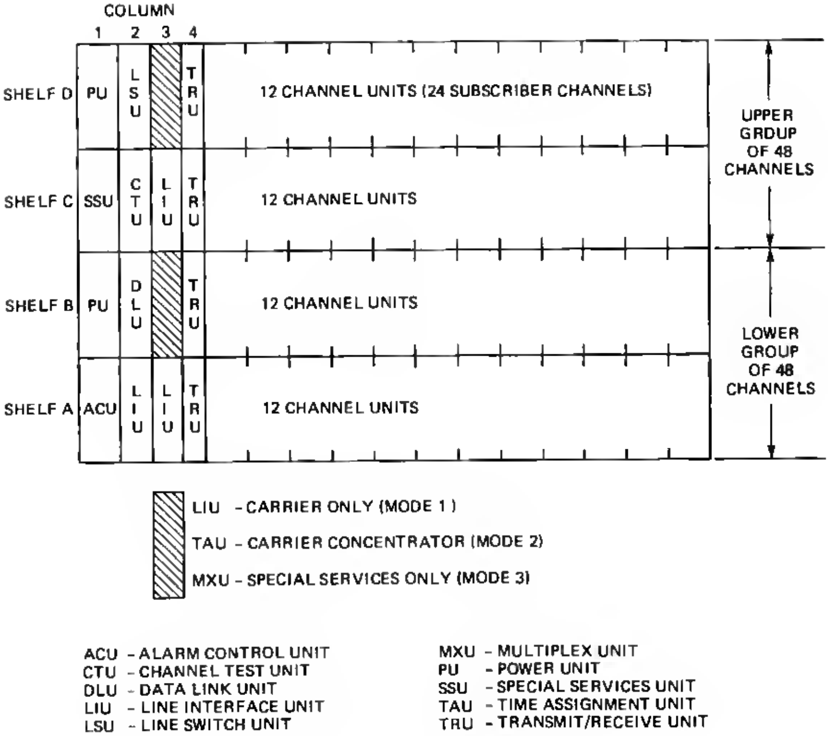

Fig. 4—The *SLC*-96 channel bank.

2.2 Operational modes

System operation is described in terms of modes of operation. Mode 1 is a pure carrier mode designed for high-traffic message telephone service and uses five T1 lines for each 96-line terminal. Mode 2 is a carrier-concentrator mode also intended for message telephone service; but it uses only three T1 lines for each terminal. This mode employs full access, two-to-one digital concentration with a capability for handling traffic sufficiently so that special loading rules are not required or used. A particular mode operates by selecting the proper common plug-in units. For Mode 2, the normal digital Line Interface Unit (LIU) is replaced by a digital concentrator plug-in called a Time Assignment Unit (TAU) using the identical physical slot in the channel bank. Mode 3 is called the special services mode, where the *SLC*-96 channel bank is loaded only with channel units designed initially for the D4 system and a new coin channel unit in the *SLC*-96 collection. It operates on three T1 lines and uses a plug-in called the Multiplex Unit, again in the same physical slot as the units mentioned previously.

III. UNIQUE LOOP CARRIER FEATURES

This section describes some of the features unique to the *SLC*-96 system. Although the *SLC*-96 system has the basic attributes of an interoffice trunk system, such as D4, it has certain special features required in the loop environment. The major differences between the *SLC*-96 and D4 systems are in T1 line powering and interface, maintenance, subscriber line concentration, and remote terminal arrangements. The operation and maintenance of a trunk-type D4 system and T-carrier lines are based on the assumption that the systems are located in central offices and that craftspeople are available at both locations. Since two craftspeople are assumed available, for example, only one alarm indicator for each transmission direction (red and yellow alarm) is required for system maintenance. While the *SLC*-96 COT is located in the central office, its corresponding RT is housed in a stand-alone cabinet, mini-hut, or other outside plant housing. This situation, unique to a loop carrier system, has resulted in a single-ended maintenance philosophy for the *SLC*-96 system, i.e., maintenance of the *SLC*-96 system at the COT location without first dispatching a craftperson to the RT. This is similar to tbe approach applied to trunk T1 systems operating in the out-state (T1/OS) environment.

Several unique features are built into the system. A T-carrier-protection switching system is integrated into the channel bank design, for which a Line Switching Unit (LSU) was developed. An Alarm Control Unit (ACU) is used to process and display various alarms originating from either the COT or RT. A Channel Test Unit (CTU) is required to allow testing of the channel units and the subscriber drop wires. An optional TAU has been developed to concentrate subscriber lines, thus saving T-carrier lines. A Data Link Unit (DLU) has been designed to provide data link circuits to handle system alarm, per-channel testing, T-carrier line switching, and concentration information between the COT and RT. Also, physical and economic constraints preclude the use of office repeater bays for the digital carrier at the COT and RT. This office repeater function has been integrated into the *SLC*-96 T1 LIU design.

The following sections will further illustrate these unique *SLC*-96 features in more detail.

3.1 T1 line interface, powering, and maintenance

3.1.1 Line interface and powering

The system constraint on available space and application of digital carrier in the loop plant required the integration of the digital line interface within the *SLC*-96 channel bank. Six unique LIUs have been designed to interface T1 carrier. The first four LIUs are used with pulp or polyethylene-insulated conductor (PIC)-insulated cable and the re-

maining two are designed for metropolitan-area trunk (MAT) or intercity and outstate trunk (ICOT) cables. The types of LIU circuit packs available and their distinguishing characteristics are:

(*i*) LIU-1 (rated A&M*)—Current regulator for low-power T1 repeater. It requires −48, ±130-volt office battery plants, dependent upon the T1-carrier span length.

(*ii*) LIU-2—Power looper for use at the RT.

(*iii*) LIU-3—Designed to interface with the office repeater or other digital systems; output level is standard DSX-1.

(*iv*) LIU-4—Similar to LIU-1 except that this unit contains a dc-to-dc converter and requires only −48-volts office battery to power the digital lines from the COT. It can be used at the RT for back powering to extend the span length.

(*v*) LIU-5—Similar to LIU-2 except that this unit is for MAT or ICOT cable.

(*vi*) LIU-6—LIU-4 version for MAT or ICOT cable.

The LIU functions as the interface between the channel bank unipolar PCM bit stream and the bipolar signal format of the T1 digital line, including the powering of a repeatered line span. This simple task grows in complexity as necessary features are added: bank clock generation, T1 line performance monitoring, status display of T1 line, and jack access for T1 line fault locate and power monitoring.

With respect to digital line powering, the repeaters in the *SLC*-96 digital line derive power from a constant current simplexed onto the carrier pairs from LIUs. Where the digital line is powered from the COT, 60-mA repeaters are required. Either 60-mA or 140-mA repeaters may be powered from an office repeater bay. Where the digital line exceeds the length that can be powered from the COT or central office CO repeater bay, additional powering spans are required. The additional powering may be provided by backpowering from the LIUs at the RT or by an intermediate remote-power-feed terminal. A remote-power-feed terminal can supply intermediate powering of long digital lines. This system option is required when the digital line power requirements exceed the range of powering from the CO (and possible extension from the RT). The remote-power-feed terminal uses *SLC*-96-type cabinets, a battery charger, and backup batteries; it also requires apparatus shelves housing constant-current dc-to-dc converters and power insertion transformers. This hardware is also suitable for frame mounting. The dc-to-dc converters operate from a nominal −48V dc and output a constant 60 mA at maximum voltages that may be optionally set at either −135 Vdc only, or ±135V.

* Manufactured for additions and maintenance only.

3.1.2 Automatic protection line switch

Although most of the trunk T-carrier lines have at least one maintenance line between offices, the maintenance line is usually only available on a manual patch basis. This kind of T1 maintenance procedure requires the services of two craftspeople and violates the *SLC*-96 maintenance philosophy. The LSU directs automatic switching to the shared protection line in the event of a digital line failure. When the trouble is removed or disappears from the main line, the LSU will automatically cause the system to switch back to the main line. This frees the protection line for use in the event of any subsequent troubles.

When not directly in use, the protection line is continually powered and monitored and carries the same bit stream as the A-shelf main line. This powering and monitoring will detect a faulty protection line if it fails while not in direct use, activating an alarm. The LSU communicates with its far-end LSU using bits assigned to it in the data link.

3.1.3 Single-ended fault location

The LIU monitors the incoming T1 bit streams and requests T1 protection switch whenever a digital line trouble occurs. If a T1 line trouble persists, the failed line may be far-end looped via manual switches on the LIU. This allows single-ended testing of the failed T1 line. The T1 lines between the COT and RT are maintained and fault-locating tests are performed using the jack panel and fault locate and order wire panel located in the COT bay.

Fault-locating tests provide a method of locating faulty repeaters or cable sections that may be causing excessive errors on the system or total signal failure. In fault-locating, bipolar violations, inserted at a voice-frequency rate, must be applied to the line under test. The signal is regenerated within an operating line repeater and part of the output is applied to the fault-locate (FL) filter in each apparatus case. The filters extract and amplify the audio component for application to a common FL line via a narrow bandpass filter. The FL line is monitored at the central office by an FL test set for the presence of this return test tone. The absence or low level of the test tone indicates a faulty repeater.

Both active and passive fault locating is applicable to the *SLC*-96 system. The two types of fault locating both use twelve unique frequency assignments. With 1114-type active filters or with passive-fault locating, the FL tests can be performed in the transmit direction only. Therefore, FL tests will be made from the COT on side 1 of the line and from the RT on side 2 of the line. With 1115-type active fault-locate filters, both side 1 and side 2 can be tested from the COT; therefore, this type is termed single-ended fault-locating. Most T1 lines can be

configured for single-ended fault-locating. A signal source will not be required at the RT; however, the line must be looped from side 1 to side 2. This can be controlled from the COT LIU, thereby eliminating a visit to the RT.

3.2 Other maintenance

3.2.1 Alarms

The alarm system for the *SLC*-96 system is designed for two levels of alarm remoting. The first level must return remote terminal alarms to the central office terminal. This is accomplished using the *SLC*-96 data link. The second level must transmit all system alarms to a remote operations center, and the *SLC*-96 system provides such an interface capability. This is in line with a growing trend toward unattended or partially attended offices with surveillance and maintenance operations centralized for a given area.

Alarm reporting for the *SLC*-96 system begins with an Alarm Control Unit plug-in in the COT and RT channel banks. This unit processes and displays common equipment alarms and transmits alarm information to the corresponding unit at the other terminal bank over the *SLC*-96 data link. At the central office, the ACUs common to a single bay pass the alarm information to a fuse and alarm panel, where the alarms are made available to the office alarm system and to a remote telemetry interface by means of relay contact closures. The primary alarm categories are: major, indicating a customer service outage; minor, indicating a trouble that has not yet affected service; power minor, indicating loss of ac power at the remote terminal; and a COT fuse alarm. In addition, the fuse and alarm panel has several status indicators, which are: a carrier line failure; near-end, or far-end, status to aid in fault sectionalization; a system identifier; and other unique alarms from a remote terminal housing called miscellaneous alarms. The miscellaneous alarms may be used for door or smoke alarms and the like.

The *SLC*-96 system is also capable of accepting a pair of remote commands from the SCC through remote signal distributor points that aid in processing alarm reports received at the remote operations centers. The first is called Bank Loop Back, which is used to interrogate the near-end/far-end status indicators for certain classes of major alarm faults. The second is a remote alarm cutoff (ACO), which is used to retire all alarm indications with the exception of the system identifier. The system identifier can only be cleared when the alarm condition for a particular system is truly cleared. The remote ACO allows processing of subsequent alarms with less ambiguity because most alarms, with the exception of the system identifier and miscellaneous alarms, are paralleled to reduce the need for alarm distribution points.

The purpose of the *SLC*-96 alarm reporting system is to alert the proper repair forces to a trouble condition and indicate urgency and a degree of fault isolation, if possible. For example, for unattended offices it would be very desirable to remotely determine whether a *SLC*-96 trouble is in or out of the central office. The *SLC*-96 alarm and status indicators provide the information to dispatch the proper craft to the proper location for many common equipment problems. Detailed Task-Oriented Practices (TOPS) are available to further isolate a *SLC*-96 trouble. Once the repair forces have been dispatched, they can use the TOP practices, built-in *SLC*-96 trouble indicators, and applicable test sets to isolate the trouble to a specific circuit pack, repeater, or cable section.

The *SLC*-96 system continuously monitors performance characteristics involving groups of channels. For the *SLC*-96 system, service-affecting troubles involving twelve or more channels constitute a major alarm condition. Per-channel troubles are viewed as a minor alarm condition and are not alarmed in the *SLC*-96 system. A trouble report for one customer usually indicates that only a single subscriber line is in trouble. This trouble may be diagnosed directly from the Repair Service Bureau (RSB) using the *SLC*-96 loop testing method to be described in the next section.

3.2.2 Loop testing feature

The requirement to provide a capability of testing the customer loop from an RSB has become increasingly important with the growing penetration of digital pair gain systems in the loop plant. The *SLC*-96 system employs a new method of testing most customer loops terminating on the RT. The method requires a new item of central office equipment called the Pair Gain Test Controller (PGTC).[6] The PGTC, under microcomputer control and in combination with circuitry in the *SLC*-96 system itself, provides switching to connect incoming RSB test trunks to a dc bypass path around the carrier system to the distribution pair. In addition, the PGTC performs an automatic test of tbe appropriate transmission and signaling of the *SLC*-96-derived channel in parallel with testing of the customer loop from the RSB.

The capability just described is offered only on the new channel units designed exclusively for the *SLC*-96 system; they include the single-party, multi-party, and coin units. The trunk and special service channel units that are a part of the D4 family are not tested from the RSB; they also cannot be tested using the PGTC. Studies are under way to develop an appropriate test access method that would, in the future, allow special service channel units used on the *SLC*-96 system to be tested from the Switched Access Remote Testing System/Switched Maintenance Access System (SARTS/SMAS).

The PGTC is a microcomputer-controlled system that operates with a pair of common circuit packs in the *SLC*-96 channel bank called Channel Test Units (CTUs), one each for the COT and RT, and that requires subscriber channel units with a test access relay at the RT. Together with a dc test pair, called a dc bypass pair between the COT and RT, the collection of hardware listed above can establish a physical connection to permit dc testing of the customer loop. This new testing method

(*i*) Presents minimal changes to existing RSB test procedures

(*ii*) Is compatible with automated test systems such as mechanized loop testing (MLT)

(*iii*) Is able to accommodate all types and lengths of loops presently testable from an RSB

(*iv*) Performs transmission and signaling testing of the derived subscriber channel

(*v*) Requires minimal circuitry within the pair gain systems, particularly at the RT, where power and space is at a premium.

As Fig. 5 sbows, the PGTC is installed in a wire center that is serving customer loops over *SLC*-96 systems. The PGTC switches office test trunks to dedicated test pairs, each of which may be shared by RTs grouped at a common location. It can test up to four channels simultaneously, provided that the channels are in different channel banks and that these channel banks do not share the same test pair. The incoming test trunks from the RSB are routed through the PGTC before they terminate on the central office switch. When the PGTC is inactive, the test trunks pass through unaltered and the PGTC is transparent to normal dialing and testing activities. The PGTC is activated only when attempting to test a customer loop served from a *SLC*-96 RT. Test access is obtained by first dialing the customer's number over one of the test trunks. This allows testing for continuity and leakage to the input of the COT channel unit. To set up the physical connection bypassing the carrier system, +116 Vdc is applied to the tip side of the test trunk. For example, at a local test desk, the reverse (REV) and positive station (+STA) keys are operated. The COT channel unit recognizes this signature and starts an elaborate interconnection sequence to cause cut-through of the test trunk directly to the customer loop at the RT. The testing facility may now perform normal testing procedures on the customers' loop via the test pair and test trunk. While these tests are in progress, the PGTC automatically checks the channel for transmission and signaling. When all testing is completed, the results of the automatic channel tests are returned to the testing facility by opening the sleeve lead of the test trunk (by operating the 3WO key). The PGTC maintains control of the sleeve lead to the central office switch to prevent the connection from being dropped during the

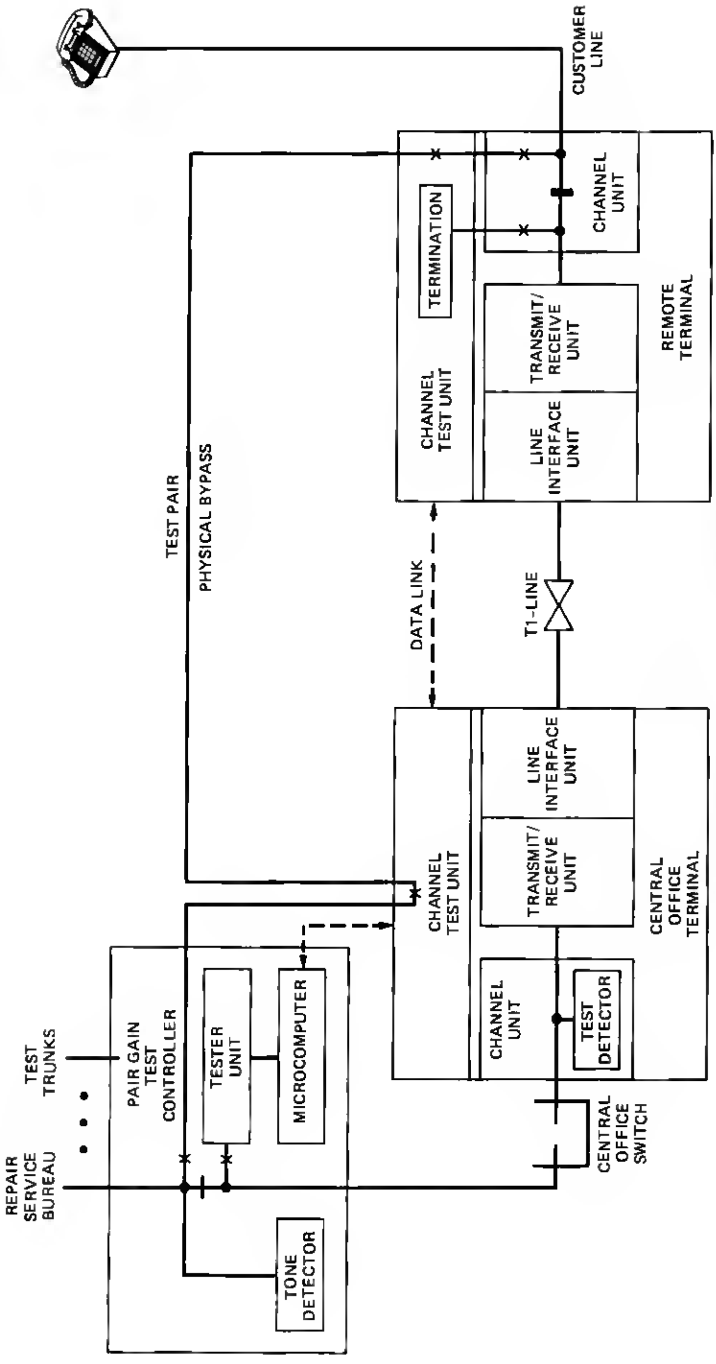

Fig. 5—Testing loops on the *SLC*-96 system.

testing interval. Results of testing are presented by audible tone bursts recognizable to a test person and by voltage levels that are more easily identified by an automated test facility such as MLT. Test results may be repeated as often as desired by closing and opening the sleeve lead.

The PGTC is a compact system consisting of a control shelf, which is always required, plus up to four expansion shelves, depending on the number of test trunks to be served. The control shelf holds the microcomputer, up to four independent tester units, and trunk cards sufficient to switch 12 test trunks. Each expansion shelf may accommodate 20 additional test trunks. The maximum system capacity is 92 test trunks. The interface between the PGTC and the *SLC*-96 systems is a bussed cable arrangement designed to handle any number of *SLC*-96 systems in the wire center.

3.3 Digital concentration

The Mode 2 system operation employs a 2-to-1 digital concentration between the central office and remote terminal to reduce the required number of T1 lines by 40 percent. Circuit packs called Time Assignment Units (TAUs) are used at both the COT and RT for each 48-channel group within the channel bank. The TAUs replace LIUs at either end of the system and require only one T1 line for each 48-channel group. The central office TAU, acting as the master controller, assigns an active channel to a specific time slot on the T1 line and transmits the assignments to the remote terminal TAU. That channel will keep its assigned time slot for the duration of the call. The concentration function is referred to as full access and any of the remaining channels may be assigned to any of the idle time slots until all time slots are active. The 2-to-1 concentration ratio requires no special traffic administration.

Figure 6 is a simplified block diagram of the concentration system operation. Each TAU circuit pack is realized with a pair of identical custom Time-Slot Interchanger (TSI) chips and a *Bellmac**-8 microcomputer. The microcomputers maintain control of channel/time-slot assignments and talk to each other over the *SLC*-96 data links. Off-hook and maintenance messages are also exchanged over the data links. The transmit TSI selectively combines two 1.544-Mb, serial PCM bit streams, one from each of the Transmit/Receive Units (TRUs) it serves. A TRU performs the analog/digital (A/D), digital/analog (D/A) and framing for 24 channels. The resulting T1 signal is sent to the receive TSI at the other end of the system, where it is expanded into two serial bit streams again.

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* *Bellmac* is a trademark of Western Electric.

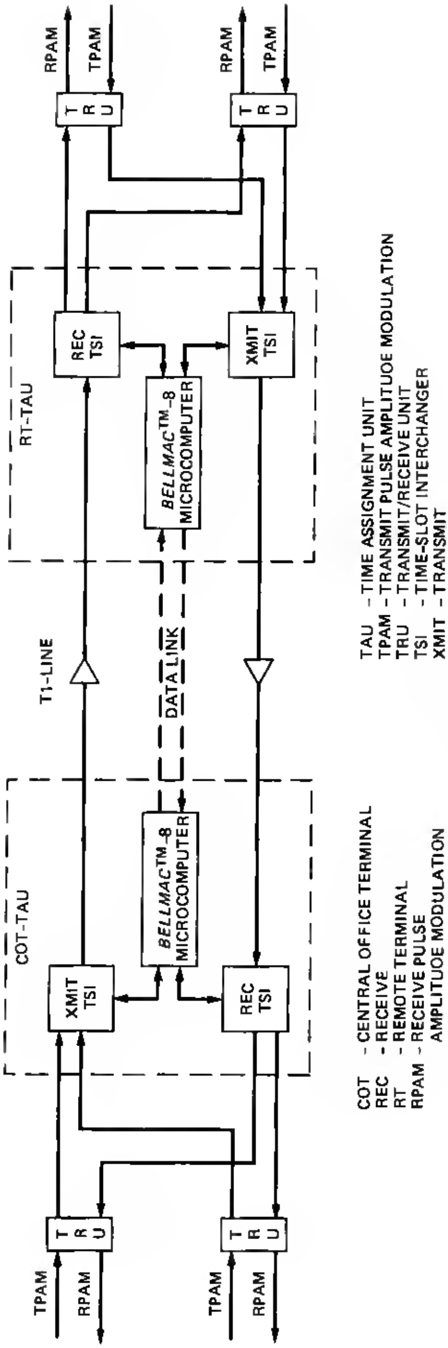


Fig. 6—Time Assignment Unit.

The need to establish a channel/time-slot assignment is initiated by detecting ringing at the COT channel unit or by detecting off-hook at the RT channel unit. This activity, as it is called, is detected by the TAU by monitoring the A and B signaling bits from each of the channels. Activity is stored in tbe TSI memory from which the microcomputer can retrieve it and establish the necessary channel/time slot-assignments. Activity at the RT is passed over the data link to the COT where channel/time-slot assignments are established.

Mode 2 operation was designed primarily for general message telephone service. The 2-to-1, full-access concentration ratio provides for a traffic-handling capability sufficient to allow full or block loading of a 48-channel group with dual single-party channel units. The concentration ratio is conservative enough to include a limited number of multi-party and/or nonconcentrated (nailed-up) special service (SS) or coin units. The maximum of eight special service or coin units is allowed for each 48-channel group. (For multi-party units the maximum number is sixteen channels for each 48-channel group.) The special service and coin units are single-channel plug-in units. Each of these units that is used in a physical slot in the *SLC*-96 channel bank reduces the number of lines to be concentrated by two. Only one time slot is nailed up and the concentration ratio remains fixed at 2-to-1. The trunk group size is reduced for each nailed-up channel unit added, which slightly decreases the traffic carried by the concentrated portion of a 48-channel group. The traffic carried by the concentrated portion of a group at 0.5-percent probability of blocking and 25-percent intrasystem traffic is presented in Table I. As we can see, Mode 2 operation of the *SLC*-96 system is significant in its traffic-carrying capability, thereby exempting the system from initial loading restrictions.

The central office TAU is designed with several traffic monitoring features. A traffic overload alarm occurs if there have been two or more blocked calls for two out of three weeks running. This activity corresponds to a weekly peak busy hour traffic in excess of nine CCS per concentrated line. This alarm may be used to initiate traffic monitoring to determine whether a two-shelf group should be deloaded. It is expected that the traffic overload alarm will occur only on rare occasions. The central office TAU contains a two-digit display that displays, upon demand, the peak traffic in CCS per concentrated line

Table I—Traffic carried at $P(B) = 0.005$ on the *SLC*-96 system versus number of lines

Number of MTS lines	48	44	40	36	32
Number of SS lines	0	2	4	6	8
Carried MTS load (CCS/line*)	12.02	11.73	11.40	11.02	10.60

* Hundred call seconds (CCS) per line.

and the cumulative number of blocked calls since the internal registers that store these numbers were last cleared. The traffic overload alarm and the internal registers, cited above, may only be cleared manually, by means of pin-jack switches on the front face of the central office TAU. The above displays are remotely monitored by traffic usage recorders using pulsed relay contact closures.

For the blocked call situation, where all time slots are in use, the central office TAU first trips ringing without billing by momentarily operating the channel unit off-hook relay and then provides a digitally generated overflow tone to tbe central office line-terminating equipment. This tone is provided for approximately 6 to 9 seconds and is used in all electromechanical offices. The electronic switching system (ESS) machines handle overflow in a different manner and use a pair of wires from the TAU to convey the blocked calls state via a relay contact closure. This signal is input to the ESS machines by master scanner applique circuits. For calls originating at the RT, dial tone is delayed until a time slot becomes available; however, there is no overflow indication.

3.4 Data link

The *SLC*-96 system contains several features that require slow-speed data links between the terminal ends. Two 2.2-kb/s data links between COT and RT carry data related to alarm remoting, channel testing, T1 automatic line switching, and concentration of the subscriber lines. The second data link carries data related to the concentrator function for the second 48-channel group in the channel bank. The data link is created by stealing some of redundant PCM bit stream framing bits. The frame organization of the *SLC*-96 system is identical to that of D4 with the 193rd bit in a frame used in a repetitive sequence for two types of framing: terminal and signal frames. The terminal frames at a 4-kb/s rate to synchronize the incoming signal on the individual 193-bit sequences. The signaling framing bas a "111000" pattern transmitted during even frames at the 4-kb/s rate to identify 6th and 12th signaling frames. Once the signaling frames have been identified, the "111000" pattern becomes redundant. By time-sharing these bits with other information, a low-speed data channel can be created. Figure 7 shows the signaling frame patterns of D4 and the *SLC*-96 system. Notice that the *SLC*-96 system "111000111000" pattern is used to identify the signaling frames and succeeding data bits. Spoiler bits are used so that the data bits cannot simulate the "111000111000" signaling frame pattern. There are four data fields, including concentrator, channel test, alarm control, and line switch for which effective data rates are 1.2 kb/s, 0.33 kb/s, 0.22 kb/s, and 0.44

BASIC FRAME PERIOD — 125 μs

1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0
ODD BIT PATTERN
D4 AND *SLC*-96 TERMINAL FRAME PATTERN
(F_T : 4-kb/s RATE)

0 0 1 1 1 0 0 0 1 1 1 0 0 0 1 1 1 0 0 0 1 1 1 0 0 0 1 1 1 0 0 0 1 1 1 0
EVEN BIT PATTERN
D4 SIGNAL FRAME PATTERN
(F_s : 4-kb/s RATE)

1 1 1 0 0 0 1 1 1 0 0 0 X X X X X X X X X X X S S S C C C A A L L L L S
EVEN BIT PATTERN
SLC-96 SIGNAL FRAMF AND DATA BIT PATTERN

S – SPOILER BITS
X – CONCENTRATOR FIELD (1.2 kb/s)
C – CHANNEL TEST FIELD (0.33 kb/s)
A – ALARM FIELD (0.22 kb/s)
L – LINE SWITCH FIELD (0.44 kb/s)

Fig. 7—Bit 193—frame pattern.

kb/s, respectively. The Data Link Unit (DLU), interacting with various units in the *SLC*-96 channel bank, provides the above functions.

3.5 Remote terminal battery plant

The *SLC*-96 RT is powered by a new, compact design battery plant that allows the terminal to operate for a minimum of eight hours during loss of commercial ac power. The battery plant employs rechargeable, sealed, lead-acid batteries as its backup source. The lead-acid system used is unique in that each cell in a battery string is truly sealed and utilizes gas recombination for long, maintenance-free operation.

The use of sealed cells eliminates the need for periodic battery maintenance by greatly minimizing problems caused by corrosion of battery posts; of course, battery watering is not required. The sealed cell also has a safety advantage in that it eliminates the possibility of damage or accidents that might previously have been attributed to electrolyte spillage when using the older flooded cells.

The battery reserve capability for a single *SLC*-96 remote terminal is implemented by connecting four KS-21906, List 4 battery packs in series to form a nominal 48-volt string. Each battery pack supplies a nominal 12 volts and is connectorized for plugging directly into a battery shelf. The connectorized battery pack, in addition to being easy to install, also is necessary for safety reasons to guard against shorting. The sealed, lead-acid battery pack exhibits very low internal impedance, which permits very high current to flow, if short circuited.

The capacity of the battery string is 25 Ah at room temperature of 25°C and at discharge rates of less than 2.5 amperes. As with most battery systems, the capacity per cycle is directly related to temperature and inversely related to the discharge rate. For the *SLC*-96

application, loss of capacity due to high discharge rates is not an issue because the long-term average drain per 96-channel system is less than 2.5A. Temperature variation, however, is another matter. All RT enclosures designed for the *SLC*-96 systems are suitable for use in outdoor environments ranging in temperature from −40° to 50°C. The battery shelves used in the *SLC*-96 RT are equipped with heaters designed to keep the batteries above −4°C in outside ambients down to −40°C. In the event of an ac power failure during the winter months, a fully charged battery string should have at least 20 Ah of capacity, which is sufficient to maintain normal equipment operation for eight hours. When the batteries are warm, battery capacity is not an issue since a fully charged string will exceed 100 percent of its nominal 25°C capacity. However, battery life is an inverse exponential function of temperature above 25°C. The KS-21906 cell has an expected life of five years when used in Bell System float-standby applications. Battery life calculations using U. S. Weather Bureau data, accounting for both mean daily high and low temperatures throughout the year in several regions of the United States, support the above-expected life. The batteries have been designed for and have been tested to operate in ambient temperatures as cold as −40°C and as warm as 65°C.

The *SLC*-96 battery plant is designed to be miscellaneously mounted in standard 23-inch frames as shown in Fig. 8. A typical arrangement consists of front-mounting a 3A battery charger along with up to two battery shelves designated 128A apparatus mountings. The battery charger, shelves, and battery packs are connectorized for easy installation. The battery charger requires 7 inches of vertical mounting space and each battery shelf requires 8 inches, for a total of 23 inches of mounting space. When the battery plant is mounted at the bottom of a 7-foot frame, there is space available to house two complete *SLC*-96 RTs including support items (ringing generators, power distribution fusing, jack panel). To conserve floor space, the battery plant requires front access only.

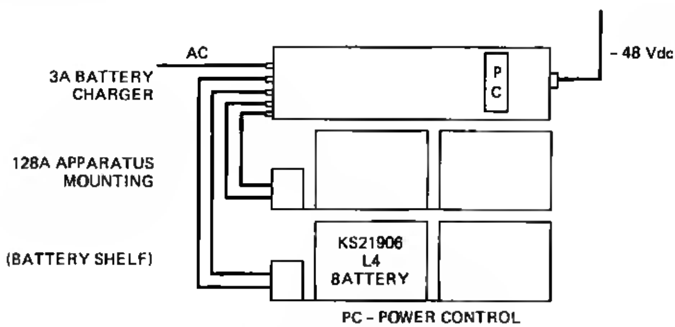


Fig. 8—The battery plant.

The 3A battery charger has been designed to power up to two *SLC*-96 RTs and can also charge up to two 25 Ah battery strings. The battery plant is a 48 Vdc plant with an 8.5A capacity and a total battery reserve of 50 Ah. The rectifier circuit in the battery charger provides two dc outputs. The primary output is 48 Vdc signal grade with 8.5A capacity to power the load; the secondary output is 64 Vdc with a 2.5A capacity to supply the battery charging circuits. The battery charger is a dual rate charger designed to return full capacity to one or two battery strings in 24 hours using a high-rate charge. It tben retains this capacity indefinitely by means of a low-rate or float charge. The rectifier uses the principle of controlled ferromagnetic resonance of a transformer to achieve regulation.

IV. PHYSICAL DESIGN AND ENCLOSURES

The general physical design used for the channel bank and associated plug-in units is covered in detail in a companion D4 physical design article.[7] However, some additional requirements that pertain to central office arrangements and remote terminal mounting will be covered here.

4.1 COT physical arrangement

COT equipment consists of a channel bank assembly, fuse and alarm panel, jack panel, and an optional T1 fault locate and order wire panel.

Figure 9 illustrates typical full-bay configurations that are possible for 7-foot, 9-foot, and 11-foot 6-inch bays. These illustrate the maximum number of channel bank assemblies that can be installed in an unequal flange bay.

4.2 RT physical arrangement

The individual remote terminal equipment designs (channel bank, battery charger, etc.) are each configured to be front-mounted to a standard 23-inch frame format. As we stated earlier, all equipment assemblies designed for RT mounting are fully connectorized to make the field installation process faster, easier, and less prone to error. In addition, these connectorized assemblies make possible very rapid removal and replacement if needed.

4.3 Enclosures

One of the primary goals in designing the *SLC*-96 system has been to enable the mounting of electronics of widely varying line sizes (from 100 to approximately 4000 lines) in different environments. This applies to outdoor mountings such as cabinets, buildings, and underground structures, as well as inside mounting in customer-owned facilities.

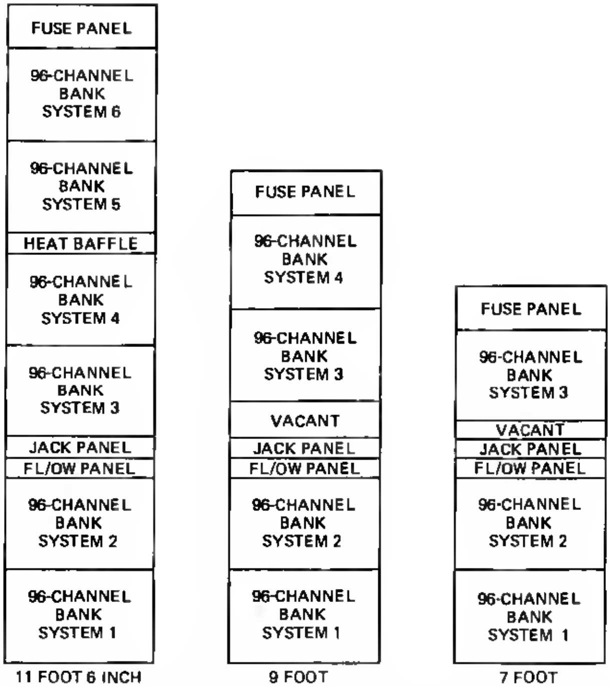


Fig. 9—Typical COT full-bay configuration for 7-foot, 9-foot, and 11-foot 6-inch frames.

There are three different outdoor cabinet designs, including a suburban cabinet, a rural cabinet, and a sign board cabinet. All three are illustrated in Fig. 10.

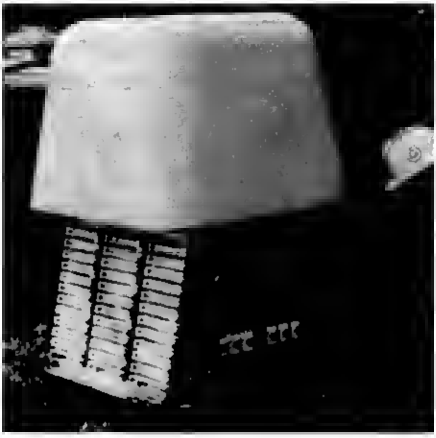
4.3.1 Suburban cabinet

The AT8908 M cabinet shown in Fig. 10 has been designed for suburban applications where appearance and site compactness are of prime importance.

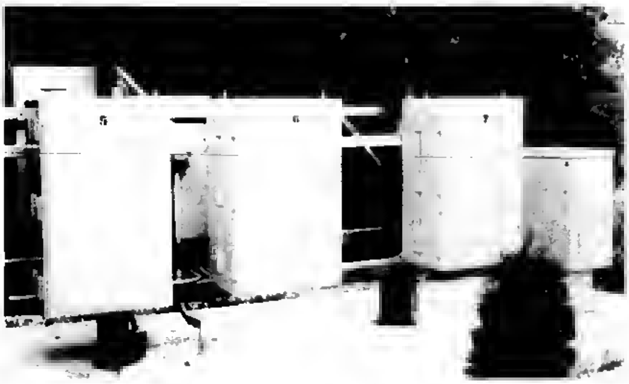
Remote terminal apparatus consists of the cabinet, one connectorized *SLC*-96 RT bank, plug-in circuit packs, connectorized power shelves, and a connectorized battery shelf and packs. With the addition of an optional frame mounting, an interconnection field may be added to the fourth side of the cabinet (required to cross-connect subscriber pairs to feeder pairs from the serving central office). The RT site may be enhanced by placing the interface inside the RT cabinet. This reduces the site size and eliminates the tombstone effect of multiple cabinets.

4.3.2 Rural cabinet

The rural (36-type) cabinet can mount one 96-channel system and has a weatherproof housing with framework very similar to the cabinet



M CABINET-1 SYSTEM



36 CABINET-1 SYSTEM

80 CABINET-2 SYSTEMS

Fig. 10—*SLC*-96 remote terminal cabinets.

used for the predecessor of the *SLC*-96 system. The *SLC*-40 cabinet was described in a previous article.[8] This cabinet is intended for areas where site appearance is relatively unimportant, and it requires that a separate interface cabinet be used.

The mounting hardware is identical to that used for the *SLC*-40 cabinets, so the newer *SLC*-96 cabinet can be mounted on poles or pedestals previously prepared for *SLC*-40 installations.

4.3.3 Community service (sign board) cabinet—80 type

This cabinet is essentially a sheet metal structure configured to resemble a sign board. The cabinet will house two *SLC*-96 systems and a large-capacity interface field. The housing is intended for applications where right of way or similar considerations preclude the use of other housings. This cabinet is a new design which has recently been introduced.

4.4 Small equipment buildings

4.4.1 Mini-hut

When several remote terminals are required at a single location, and land can be obtained, a hut can achieve savings over multiple-cabinet installations. Also, as we see in Fig. 11, the mini-hut makes it easier to provide an aesthetically designed installation than can be achieved with multiple collocated cabinets.

The *SLC*-96 mini-hut is approximately 6 feet by 10 feet by 8 feet high and is designed to accommodate ten *SLC*-96 systems. For hut-mounted applications the *SLC*-96 RT equipment is mounted on standard 7-foot equipment frames with two complete 96-channel systems and ancillary power equipment for each frame. Thus, five frames are used in a 10-system mini-hut.

To conserve floor space (and thereby enhance appearance and decrease costs) the *SLC*-96 equipment requires front access only. Rear access to the channel banks can be obtained by mean of an access shelf. The access shelf is a sheet metal design that allows the channel bank to be removed from the framework, slid out from the frame, and pivoted for rear access.

The mini-hut is usually ordered equipped with frames, shelves, cross-connect field, and inside cabling. Western Electric assembles this arrangement and ships the fully equipped hut, without plug-ins, to the RT site.

4.4.2 Electronic equipment enclosure

Another small building design is available for applications requiring more than 10 collocated systems. This is the electronic equipment enclosure (EEE), which has about a 10- by 20-foot floor area and can

EEE-40 SYSTEMS

MINI-HUT-10 SYSTEMS

CEV-20 SYSTEMS

Fig. 11—*SLC*-96 remote terminal enclosures.

be equipped with up to forty 96-channel systems on 20 7-foot frames (see Fig. 11).

The EEE (and mini-hut) appearance was developed in conjunction with an industrial design firm, Henry Dreyfuss Associates, to provide an appearance that is judged to be acceptable by most community standards. The cost of the standardized, prefabricated EEE can be expected to be lower than a conventionally constructed Bell System building of comparable size and quality. In addition, the installation interval is drastically reduced over that for conventional construction.

4.5 Controlled environment vault

Above-ground structures, both cabinets and huts, are appropriate choices for RT housing in areas where suitable sites can be found and land can be obtained. However, such sites become increasingly less prevalent as the RTs get closer to the serving central office (and hence into increasingly populated areas). In some sections of this country, such as large parts of the Northeastern United States, it is extremely difficult to find suitable above-ground sites. The Controlled Environment Vault (CEV) has been designed for such applications and is economically very attractive when land costs become appreciable.

The CEV design for *SLC*-96 systems is a 6-foot wide, 16-foot long, 9-foot high, two-piece precast concrete structure with environmental controls and alarms and a palletized *SLC*-96 equipment arrangement. The structure can accommodate ten 7-foot *SLC*-96 racks, or 20 systems, as illustrated in Fig. 12.

4.6 Customer premises arrangements

SLC-96 systems can often be very effective for serving large, single-customer needs, or for other applications where the equipment can most easily be placed indoors on the customer's premises. For these applications, the *SLC*-96 RT equipment is most often mounted on 7-foot racks, as for the previously mentioned large outdoor structures, and placed in telephone equipment rooms. These rooms are areas on a customer's premises where access is limited to telephone personnel only. Such space may already exist in some buildings, while in others, leasing, etc., arrangements may be required.

A future Bell System Technical Journal article is planned to cover the physical design of the *SLC*-96 system in greater detail.

V. SUMMARY

The *SLC*-96 system is fulfilling its traditional role in the loop plant, where it is used as an alternative to capital expenditures for new cable, new structure, or new central offices to provide growth of general message telephone service. In addition, the *SLC*-96 system has the

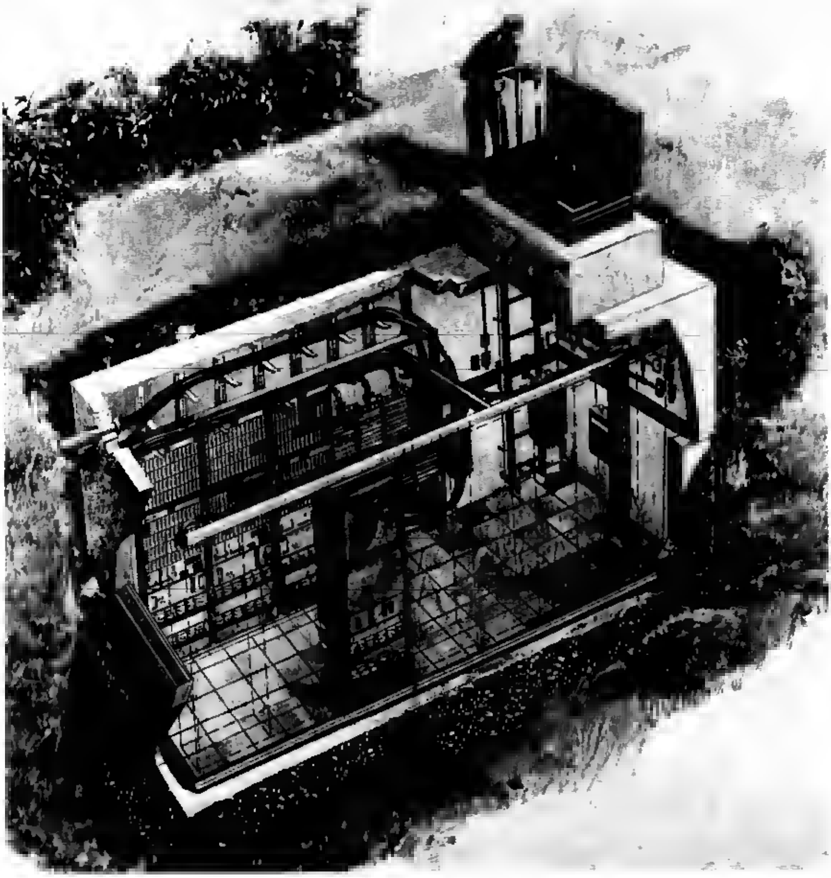


Fig. 12—The Controlled Environment Vault.

versatility to offer services in a variety of new applications, especially involving services to business customers. Digital loop carrier will become even more attractive as digital switching becomes more predominant for both local central offices and private branch exchanges (PBXS). The *SLC*-96 system design approach was based on the D4 system architecture. This approach was chosen to widen the range of application of a digital loop carrier in the Bell System in a timely and cost-effective manner. The capability of the *SLC*-96 system has combined, in one system, many of the attributes of an interoffice trunk system with the unique requirements of a loop carrier system.

REFERENCES

1. A. J. Ciesielka and N. G. Long, "New Technology for Loops—A Plan for the '80's," IEEE Trans. on Comm. (July 1980), pp. 923–30.

2. S. Brolin, Y-S. Cho, W. P. Michaud, and D. H. Williamson, "Inside the New Digital Subscriber Loop System," Bell Lab Rec. (April 1980), pp. 110–16.
3. J. W. Olson, "The *SLC*™-96 System," Natl. Telecomm. Conf., *2* (November 1981), pp. D3.4.1–5.
4. G. E. Harrington, D. H. Morgan, and J. W. Olson, "Survey of Pair Gain System Applications," Proc. of ISSLS '80, *73* (September 1980), pp. 196–200.
5. G. J. Greco and D. H. Morgen, "Applications of the Digital Loop Carrier in the '80s," Natl. Telecomm. Conf., *2* (November 1981), D3.1.1–7.
6. K. H. Swanson, "A New Approach to Testing Loops Served by Pair Gain Systems," NTC Conf. Rec., *3* (November 1979), Section 51.6, pp. 51.6.1–5.
7. W. G. Albert, A. G. Favale, J. R. Hall, and D. H. Klockow, "The D4 Digital Channel Bank Family: Digital Terminal Physical Design," B.S.T.J., this issue.
8. R. W. Henn and D. H. Williamson, "Loop Plant Electronics: Physical Design Considerations," B.S.T.J., *57* (April 1978), pp. 1185–1223.